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Sintered rotor for rotary pump - has trochoidal rotors with dimensions derived from given formula
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The sintered rotor for a rotary pump has a curve in the form of a trochoid so that a gap (g) between an inner rotor (1) and an outer rotor (2) remains constant throughout the overall circumference of each of the rotors. The trochoid dimensions are chosen using a given formula, including diameter of the base circle, rolling circle, and eccentricity ratio and given constants.

The value of distance between the centres of circular arc teeth at the outer rotor is used in a given formula also using the corrected value of a radius of the circular arc. (13pp Dwg.No.1/9)
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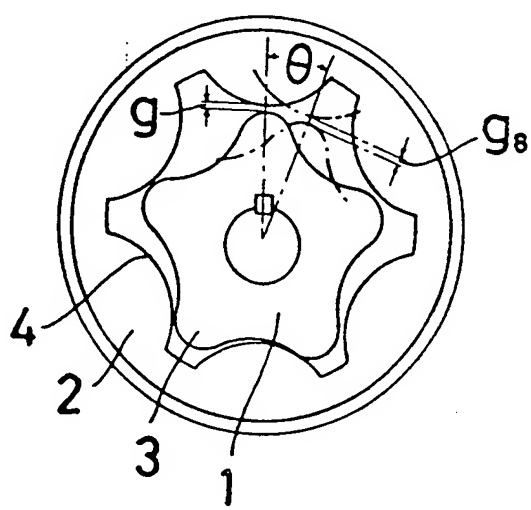

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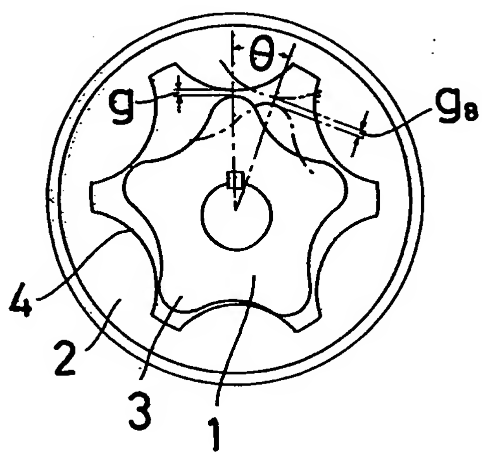
(54) **A sintered rotor for a rotary pump and a manufacturing method for the rotor.**

(57) A sintered rotor for a rotary pump utilizing the trochoidal curve and a manufacturing method for the rotor, the rotor being formed to make a combinational gap (g) between an inner rotor (1) and an outer rotor (2) as smaller and constant as possible because both the inner and outer rotors are not rotatable when the gap obtained from the dimensions of the curve of the inner rotor and the theoretical curve of the outer rotor, as the wellknown envelope of circular-arc group centered on the trochoidal curve, when given a diameter of a base circle, that of a rolling circle, an eccentricity and a diameter of a rotary path, is zero; so that, when a ratio of the base circle diameter to the rolling circle diameter is represented by n, the rotor is applicable to a special tooth form of the ratio n even other than the integer.



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A sintered rotor for a rotary pump and a manufacturing method for the rotor

This invention relates to a sintered rotor for a rotary pump and a manufacturing method for the rotor.

An inner rotor for the rotary pump utilizing the trochoidal curve, when given a diameter A of a base circle, that B of a rolling circle, an electricity e, and a diameter c of a rotary path, can obtain an inner rotor curve TC as the envelope of circular-arc group centered on the trochoidal curve T, and also a theoretical curve of an outer rotor is obtained.

In this case, a combinational gap g between the inner and outer rotors from the above dimensions is zero so that both the rotors are not rotatable. Hence, in fact, the curve of inner rotor is corrected to be smaller, or that of outer rotor larger, thereby producing the combinational gap g through which both the rotors become rotatable.

Such correction for the curves at present is carried out experimentally so that the combinational gap g of each part in a commercial rotary pump utilizing the trochoidal curve is not constant to fluctuate following a change in a rotary ange θ , in which the regulation S is given by the equation:

$$S = \frac{g\ max. - g\ min.}{g\ max.}$$

The regulation S, as shown by the dotted line in Fig.2, is about 60~80 %, which is made smaller, in other words, the combinational gap at each part is made about constant and smaller, thereby enabling an improvement in the performance of the pump.

However, when the maximum combinational gap g max. is made smaller, the minimum combinational gap g min. portion causes interference with teeth to lead to poor rotation of the pump, whereby the combinational gap is restricted in its diminution.

For diminishing the gap regulation the following methods are proposed:

(a) To select a smaller eccentricity ratio fe = $\frac{e}{B}$

(b) To properly correct the theoretical curve of the outer rotor.

(c) To reasonably combine the above methods (a) and (b).

In addition, in case that the correction by the method (b) is proper even for the inner rotor not adopting the method (a), the regulation S can be made smaller to a certain extent, but is limited.

Conversely, even under consideration of the method (a), the correction of the curve of outer rotor, if not proper, cannot diminish the regulation S.

This inventor has filed the Japanese Patent Application (application No. Sho 54-57214) of the rotor for the rotary pump of the curve formed in combination of the methods (a) and (b) to have the regulation S of 60 % or less and also the Patent Application (application No. Sho 54-57213) of the correction for the theoretical curve of the outer rotor.

The inventor, after promoting the research since then, has found out that, in the case where the nummber of teethof the inner rotor in the Patent Application No. Sho 54-57214 is the integer n, not obly the eccentricity ratio fe but also a ration A/B between the base circle diameter A and the rolling circle diameter B are represented by n, whereby the correcting method of the curve

can correspond not only to the number of teeth of the integers n = 1, 2 , 3 .... but also to the special tooth form of the number of teeth included in the hatched area in Fig. 3, in which n = 4.5, n = 5.5 ... are shown. Furthermore, the inventor has found out that, when this method is applied to design of a metallic mold used for manufacturing the sintered rotor so that the metallic mold is used to produce the sintered rotor, a desired sintered rotor can be produced. As a result, the inventor has designed this invention.

The invention will hereinunder be described in detail in reference to the accompanying drawings,
Fig. 1 is a view explanatory of a combinational gap of an inner rotor and an outer rotor utilizing the trochoidal curve,
Fig. 2 shows curves of change in combinational gap between both the rotors,
Fig. 3 is a view showing the relation between n and fe,
Fig. 4 and 5 are views explanatory of the dimensions in the design of rotor utilizing the trochoidal curve,
Fig. 6 shows curves of the gap regulation at a commercial oil pump rotor,
Fig. 7 is a view explanatory of the correction elements for the outer rotor's curve of the invention,
Fig. 8 shows the curve of the gap regulation after the outer rotor's curve is corrected, and
Fig. 9 shows the curve of the relation between a corrected value ($\Delta b + \Delta c$) and the gap regulation.

An object of the invention is to provide a sintered rotor for a rotary pump utilizing the trochoidal curve and a manufacturing method for the rotor, characterized in that the rotor has the curve form satisfying the following conditions for the purpose of making the

combinational gap between the inner rotor and the outer rotor about constant throughout the overall circumference, that is,

(1) the trochoid dimensions are so selected that when among them the base circle diameter is represented by A mm, the rolling circle diameter by B mm, the eccentricity by e mm, the eccentricity ratio by $f = \frac{e}{B}$, and a ratio A to B by n, the following inequality and equation are satisifed:

$$0 < fe \leqq fe\ (n)$$

$$fe\ (n) = a_0 + \frac{a_1}{n} + \frac{a_2}{n^2} + \frac{a_3}{n^3} + \frac{a_4}{n^4},$$

where a_0, a_1, a_2, a_3, and a_4 are the constants as $a_0 = 0.5$, $a_1 = 1.434$, $a_2 = -19.79$, $a_3 = 51.02$ and $a_4 = -33.11$ respectively, and

(2) when a corrected value of a distance between the center of each tooth in a circular arc at the outer rotor and the center of the outer rotor, is represented by Δb mm, and a corrected value of a radius of the circular arc by Δc mm, the Δb and Δc satisfying the following inequality are selected to correct the outer rotor's curve:

$$|\Delta b| + |\Delta c| < 0.3 \text{ mm, where } \Delta b > \Delta c.$$

Fig. 1 shows a relation between an inner rotor 1 and an outer rotor 2, in which a gap g, when a tooth 3 at the inner rotor 1 is opposite to a tooth 4 at the outer rotor 2, is shown by the solid line, and a gap $g\theta$, when the tooth 3 at the inner rotor 1 rotates at a rotary angle θ, is shown by the dot-and-dash line, where $g \fallingdotseq g\theta$.

In the present invention, the eccentricity ratio fe satisfying the condition (1) claimed in the claim

varies due to a value of n $(\frac{A}{B})$, whereby the theoretical computation and actual product have been affirmed and then eccentricity ratio with respect to the value of n has been computed, the result of which is given by

$$0 < fe \leqq fe\ (n)$$

$$fe\ (n) = a_0 + \frac{a_1}{n} + \frac{a_2}{n^2} + \frac{a_3}{n^3} + \frac{a_4}{n^3}$$

where a_0, a_1, a_2, a_3 and a_4 are the constants as a_0=0.5, a_1 = 1.434, a_2 = -19.79, a_3 = 51.02 and a_4 = -33.11 respectively.

Concretely, when the eccentricity ratio fe is selected within a range of an hatched area in Fig. 3 showing the relation between fe and n, the gap regulation S can be kept in 0 to 60 %, the eccentricity ratio fe being widened of its selection range as n increases and the gap regulation S decreases as fe decreases.

For example,

(a) while S=70 % at the eccentricity ratio fe=0.4 when n=4.5, the regulation S can be diminished to 45 % at fe=0.3 and to 20 % at fe=0.2,

(b) while the regulation S is 60 % at fe=0.4 when n=6, S can be diminished to 25 % at fe=0.3 and to 57 % at fe=0.2, and

(c) while the regulation S is 60 % at fe=0.49 when n=10, S can be diminished to 25 % at fe=0.4, 11 % at fe=0.3, 5 % at fe=0.2, and 2 % at fe=0.1.

As seen from the above, the above values correspond to the minimum value in 60 to 80 % or the limit value less than that, of the combinational gap regulation at a commercial oil pump rotor, so that a value fe in a range less than the above value is selected to diminish the value S and combinational gap g, thereby remarkably improving the performance of the pump, especially the

volumetric efficiency under high pressure.

In addition, Figs. 4 and 5 illustrate the dimensions in the design of the rotor utilizing the trochoidal curve.

Next, the condition claimed in claim (ii) will be described referring to Fig. 7 showing the correction elements for the curve of outer rotor. Now, a corrected value ($c_2$mm - $c_1$mm) of radius of circular-arc of the tooth in the theoretical curve of outer rotor 2 is presented by Δ c mm, and that ($\overline{OO}_2$mm - $\overline{OO}_1$mm) of the distance b between the centers of circular arcs, by Δ b mm, conventional correction is as about Δb=+0.2 to 0.4 mm (symbol + designates the direction of enlarging the distance btween the centers) and Δc=+0.1 to 0.3 mm (+: the direction of enlarging the radius). Referring to Fig.6, when the rotary angle θ of inner rotor 1 at the commercial pump is expressed by the abscissa axis and the gap g by the coordinate axis, the curve becomes as shown in Fig. 6, in which, if the maximum gap g max. is diminished as shown by the dotted line, at the point a of the g min., the interference with the tooth occurs to restrict in diminishing maximum gap.

This invention is characterized in that as a result of analysis by confirming the corrected values regarding the theoretical computation and an actual product of the combinational gap, the combinational gap regulation S and g max. and g min., when given the trochoid dimensions, each become the function of the corrected value Δ b of the distance between the centers of circular arcs and of Δ c that of the radius of circular arc, as given by

$$g\ max. = f_1\ (\Delta b, \Delta c),$$
$$g\ min. = f_2\ (\Delta b, \Delta c),\ and$$
$$S = f_3\ (\Delta b, \Delta c),$$

so that the corrected values Δ b and Δ c are selected to keep the sum of absolute values of Δb and Δc less than 0.3 mm, whereby the gap regulation S becomes smaller than that of the conventional commercial pump (under 60 %) and the undulation at the curve of the gap variation becomes smooth as shown in the gap regulation curve when the outer-rotor's curve is corrected as shown in Fig. 8, resulting in that the pump rotation is kept proper.

In this case, however, the combinational gap g becomes minus unless Δ b and Δc have a relation of $\Delta b - \Delta c > 0$ therebetween.

For example, in the conventional mass-produced oil pump with the outer rotor of an outer diameter of 40 mm, when $\Delta b = 0.3$ mm and $\Delta c = 0.25$ mm, $|\Delta b| + |\Delta c| = 0.55$ mm and g max. of 108μ and g min. of 32μ are obtained to result in the gap regulation S of 70 %, and when $\Delta b = 0.15$ mm and $\Delta c = 0.1$ mm, $|\Delta b| + |\Delta c| = 0.25$ mm and g max. of 123μ and g min. of 67μ are obtained to get S=46 %, whereby in a range of

$$|\Delta b| + |\Delta c| < 0.3 \text{ (where } \Delta b > \Delta c\text{)},$$

the minimum value of gap regulation to the outer-rotor's curve is obtained, thus making it possible to similarly obtain the minimum value of gap regulation regarding various types of the rotor.

Referring to Fig. 9, the above corrected value $|\Delta b| + |\Delta c|$ is taken as the abscissa axis and the gap regulation S as the coordinate axis and the curve shows the relation between $|\Delta b| + |\Delta c|$ and S. As seen from the curve, the gap regulation is diminished and the maximum combinational gap g max. is made smaller to nearly equalize the gaps between the respecrtive parts, thereby improving the performance of pump, especially , the

volumetric efficiency under high pressure.

Especially, the present invention characterized by representing by n not the number of teeth at the inner rotor but the ratio, i e., $\frac{A}{B}$, of the base circle diameter A to the rolling circle diameter B, can obtain various tooth forms based on the trochoidal curve within the range of hatched portion in Fig. 3 and of $\frac{A}{B}$ not the integer (e.g. n=4.5).

Now, the rotor of the invention may be produced by a machining process, but it is rather effective in the manufacturing cost and performance to mass-produce the sintered rotors with a noticable feature of using the metallic mold.

The present invention also is applicable to a technical design for the metallic mold used for manufacturing the rotor.

Next, explanation will be given on the application of the invention to the technical design of the metallic mold.

Conventionally, the metallic mold utilizing the trochoidal curve has been designed and produced in such a manner that a template is made to conform with a handmade enlarged drawing of the curve and then the metallic mold is machined by use of the template, but it has been very difficult to maintain the accuracy of sintered parts which tend to cause a change in dimension during the sintering process, especially the accuracy of tooth form, even after the sintering process. Hence, usually, the product has been applied with a repress work (sizing) as the tooth reforming. In case that the product does

not conform with a desired accuracy, the remedy therefor is to partially correct the handmade enlarged drawing. Such method in a trial and error manner, however, not only takes much time and expenses to get a desired tooth form, but also makes the produced metallic mold impossible to exactly express the dimensions for design.

On the contrary, the present invention and a computing system made for attaining the purpose thereof are applied to make it possible to design a metallic mold for molding and sizing to meet with variation of the size and the dimensions of the desired form of product during the sintering process of powdery material.

In other words, after designing the product of a desired form under the dimensions, in view of a rate of change in dimension during the sintering process and a proper allowance for the reforming during the sizing process, the designing dimensions for the metallic mold are redetermined by the same method and then the mold of said dimensions is produced by a metallic mold machining machine, e.g., a wire cut machine. Such method has possibility of saving the sizing process conventionally necessary and also can provide a rotor of sintered parts which is inexpensive and of high quality.

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Claims:

1. A sintered rotor for a rotary pump utilizing the trochoidal curve, characterized in that said rotor has a curve in a form to satisfy two conditions so that a combinational gap (g) between an inner rotor (1) and an outer rotor (2) becomes about constant throughout the overall circumference of each of said rotors, said conditions being that

(i) when among the trochoid dimensions a diameter of a base circle is represented by A mm, that of a rolling circle is represented by B mm, an eccentricity is represented by e mm, an eccentricity ratio is represented by $fe = \frac{e}{B}$, and a ratio $\frac{A}{B}$ of the diameter A to that B is represented by n, the trochoid dimensions are so selected that fe satisfies the following inequality and equation:

$$0 < fe \leqq fe\ (n), \text{ and}$$
$$fe\ (n) = a_0 + \frac{a_1}{n} + \frac{a_2}{n^2} + \frac{a_3}{n^3} + \frac{a_4}{n^4}$$

where a_0, a_1, a_2, a_3 and a_4 are the constants as $a_0 = 0.5$, $a_1 = 1.434$, $a_2 = -19.79$, $a_3 = 51.02$ and $a_4 = -33.11$, respectively, and

(ii) when a corrected value of a distance between the centers of circular-arc teeth at said outer rotor (2) is represented by Δ b mm and a corrected value of a radius of the circular arc is represented by Δ c mm, said Δ b and Δ c are so selected that the following inequality holds:

$$|\Delta b| + |\Delta c| < 0.3 \text{ mm, where } \Delta b > \Delta c,$$

thereby correcting the curve of said outer rotor (2).

2. A manufacturing method for a sintered rotor for a rotary pump utilizing the trochoidal curve, characteriz ed in that a metallic mold is used for molding and/or

sizing said rotor, said metallic mold being designed by use of the trochoid dimensions such that when a diameter of a base circle is represented by A mm, that of a rolling circle is represented by B mm, an eccentricity is represented by e mm, an eccentricity ratio is represented by $fe = \frac{e}{B}$, and a ratio $\frac{A}{B}$ of the diameter A to that B is represented by n,fe satisfies the following inequality and equation:

$$0 < fe \leqq fe\ (n) \text{ and}$$

$$fe\ (n) = a_0 + \frac{a_1}{n} + \frac{a_2}{n^2} + \frac{a_3}{n^3} + \frac{a_4}{n^4}$$

where a_0, a_1, a_2, a_3, and a_4 are the constants as $a_0 = 0.5$, $a_1 = 1.434$, $a_2 = -19.79$, $a_3 = 51.02$ and $a_4 = -33.11$ respectively.

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FIG. 1

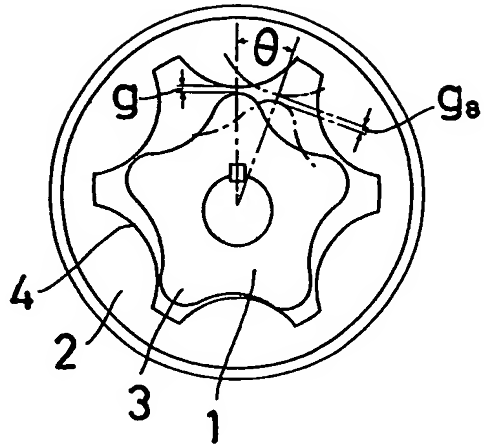

FIG. 4

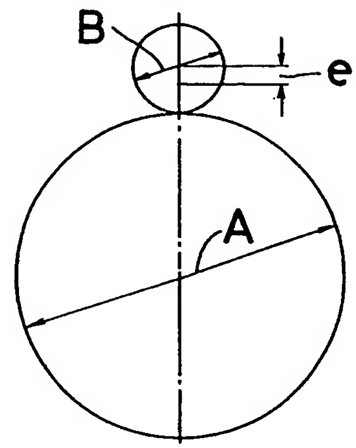

FIG. 2

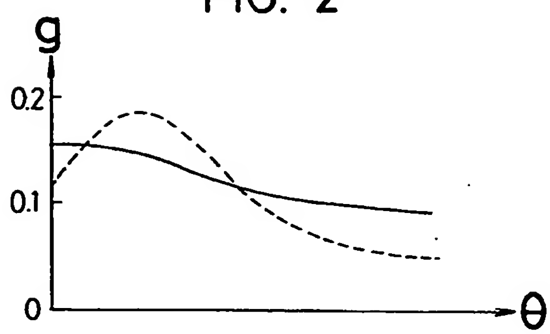

FIG. 5

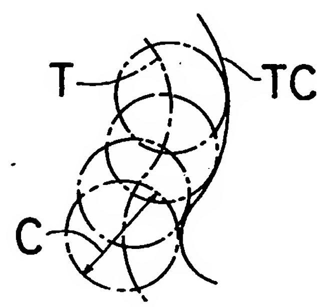

FIG. 3

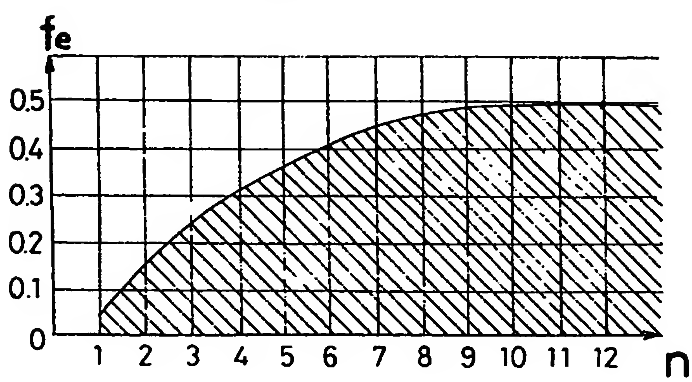

FIG. 6

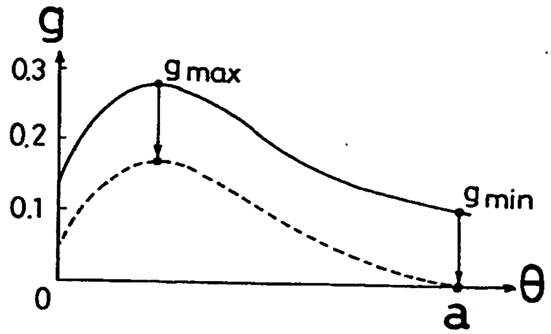

FIG. 8

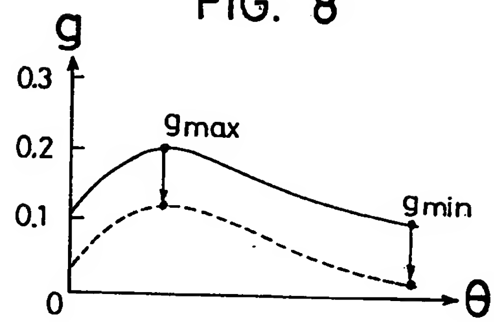

FIG. 7

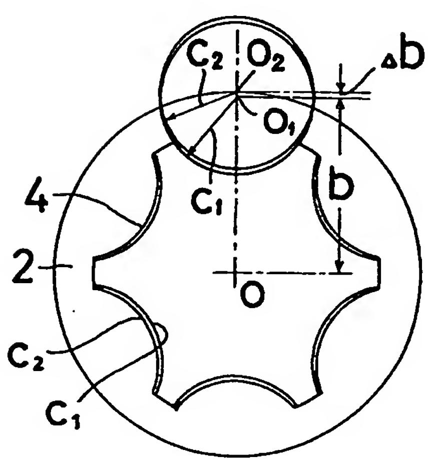

FIG. 9